Cold Test and Large Signal Simulator (CTLSS) for RF Solid State Circuit Applications

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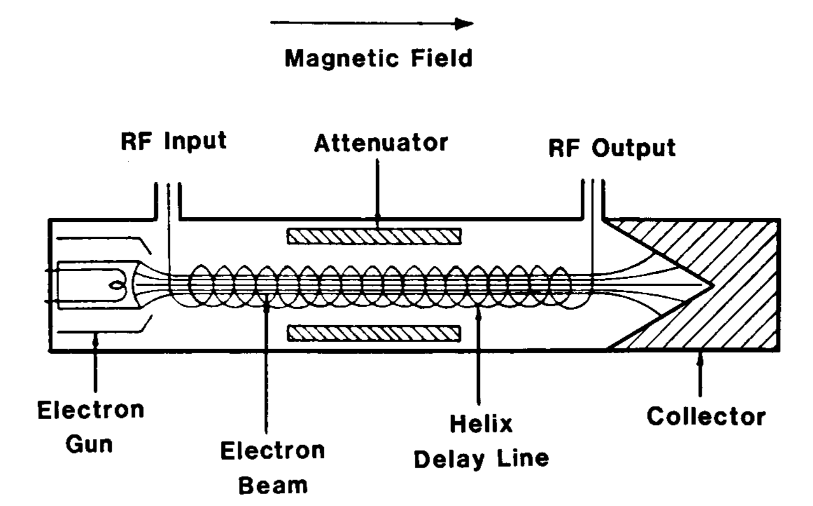
CTLSS Code



- Electromagnetic Model Features
  - **Frequency domain**
    - **resonant and driven problems**
  - **3D model**
    - **Includes complex geometry**
  - **Finite Integration Technique**
    - **Combines best features of Finite Difference and Finite Element approaches**
      Supports conformal gridding

- Material Properties
  - **Complex permittivity and permeability**
  - **Anisotropic**
  - **Nonlinear**
  - **Dispersive**

- Output
  - **Fields**
  - **Mode characteristics (frequencies, impedance, Q, S parameters)**

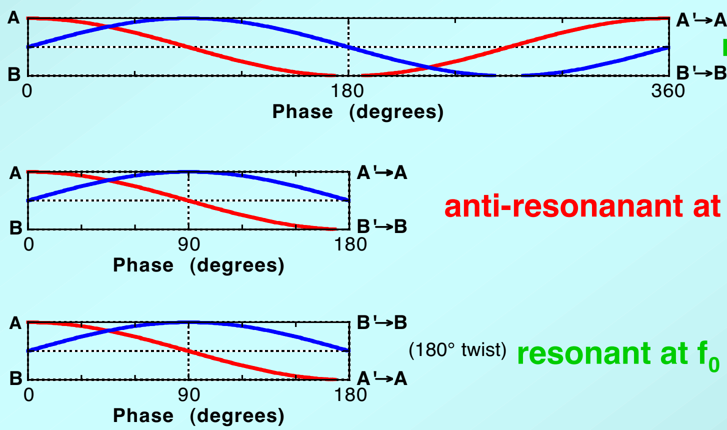
- RF Solid-State Circuit Applications
  - **Passive devices (filters, phase shifters …)**
  - **Active devices (FETs, …)**
  - **Electromagnetic fields**

Existing capability
Work in-progress
Future work

Möbius Resonator

- **Combine phase shift due to time delay (electrical length) with phase shift due to a geometric deformation**
  - **realize resonance at half the frequency of the “conventional” geometry**
  - **reduce the size, weight, and volume of a resonator**
  - **a wire defines the boundary circle & an electric field flux line is the surface**

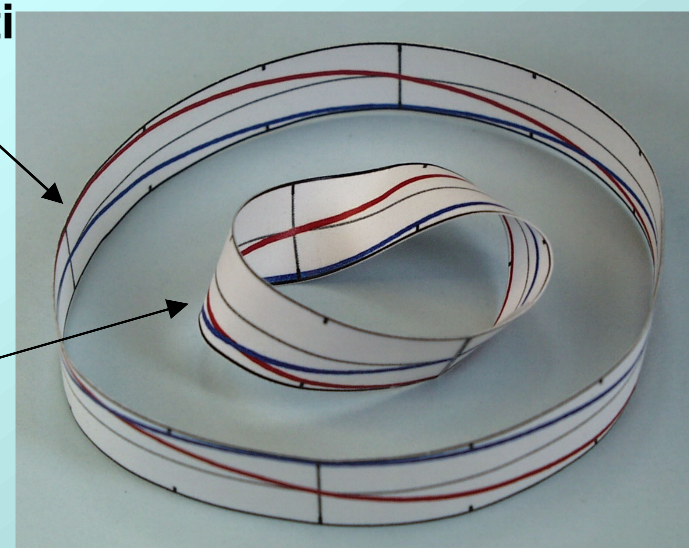
- **The unique properties (periodic “flipping” between “left handedness” and “right handedness”) of non-orientable surfaces are compatible with the spatial oscillation of an electromagneti**



resonant at f_0

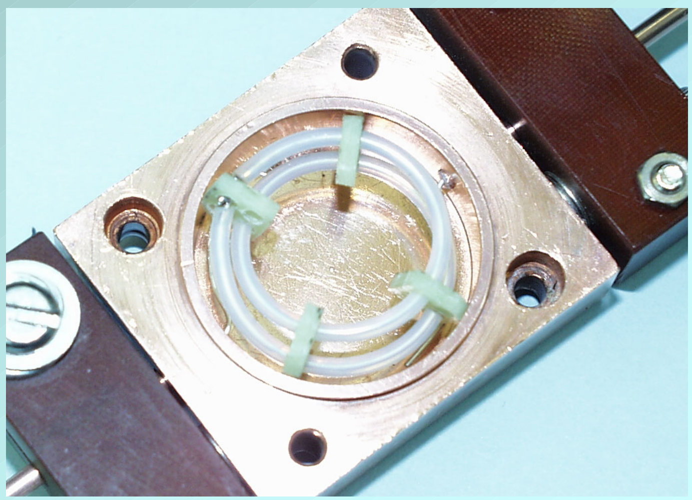
anti-resonanant at f_0

resonant at f_0

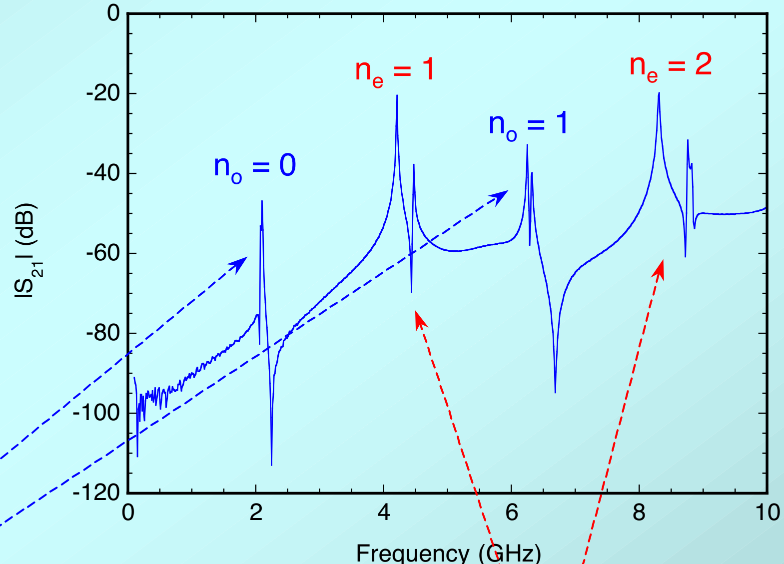


Möbius and Non-Möbius Modes

Möbius wire resonator in a 1-inch diameter copper cavity



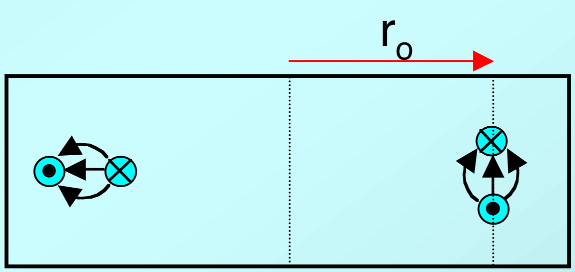
Measured response of a loosely coupled Möbius wire resonator



Mobius modes: Coupled line generalized odd modes

Resonant condition: $2\pi r_o = (2n_o+1)\lambda/2$, $n_o = 0, 1, 2, \ldots$

Currents are in the wire only and the E fields are concentrated between the wires

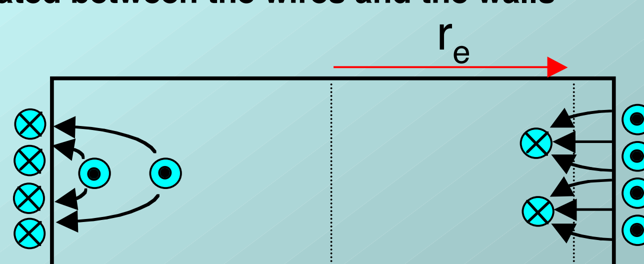


cross sectional edge view

Non-Mobius modes: Coupled line generalized even modes

Resonant condition: $2\pi r_e = n_e\lambda$, $n_e = 1, 2, 3, \ldots$

Currents are in the wires and walls and the E fields are concentrated between the wires and the walls

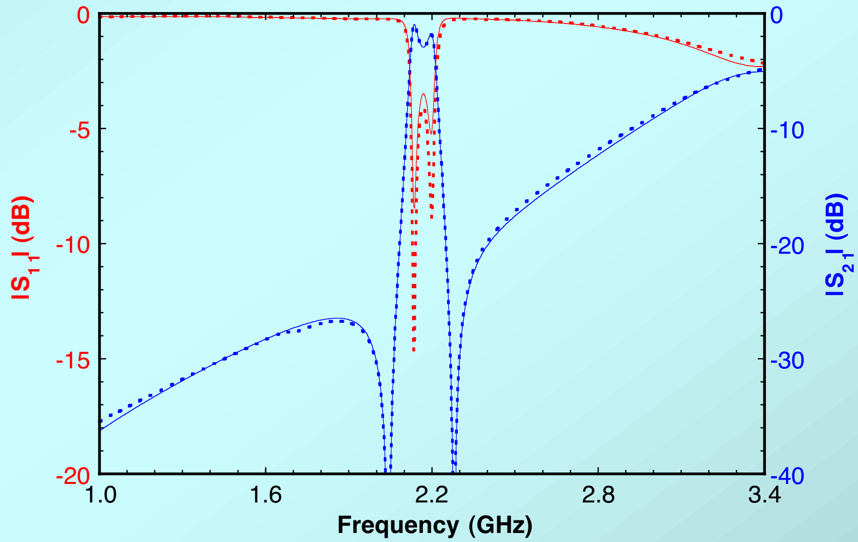


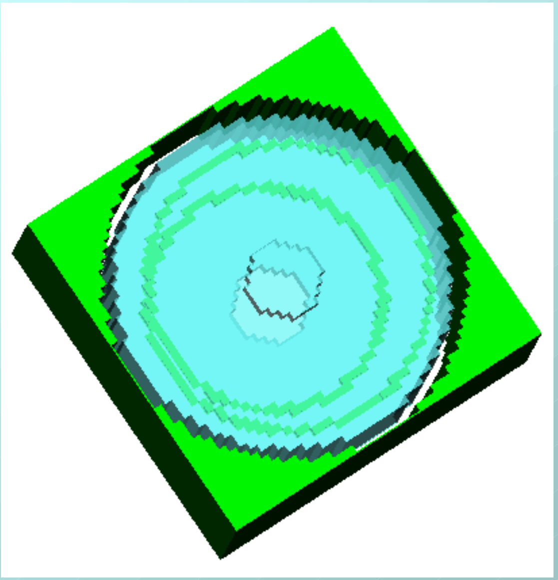
cross sectional edge view

Möbius Filter

- **Advantages:**
  - Dual-mode
  - Two intrinsic transmission zeros
  - 4 X reduction in volume
- **Problems:**
  - Coupling to even modes degrades "out-of-band" performance above the passband
  - Möbius wire can not physically "float" in cavity
  - No thermal path from Möbius wire to cavity wall (for high power handling)
  - No dielectric filling to further reduce size
- **A solution: use dielectric puck with air gap at the cavity walls**
  - provide contact to end walls near center only
    - provides thermal path
    - positions resonator precisely
  - Möbius mode resonances reduced approximately by square root of ε_r
  - fields of even modes are concentrated in the air gap shifting these resonances to much higher frequencies compared to a completely filled cavity

Measured filter response (without tuning)

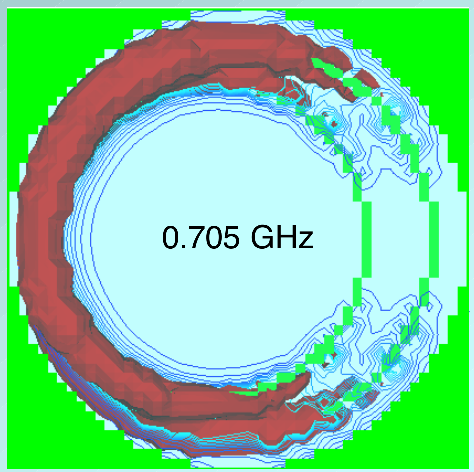




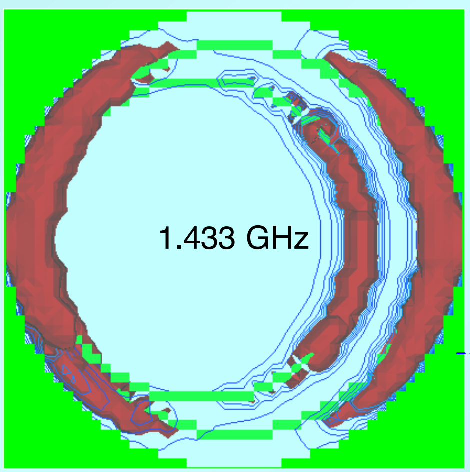
CTLSS 3D EM Modeling of Modes

Dielectric filled

Odd Mode

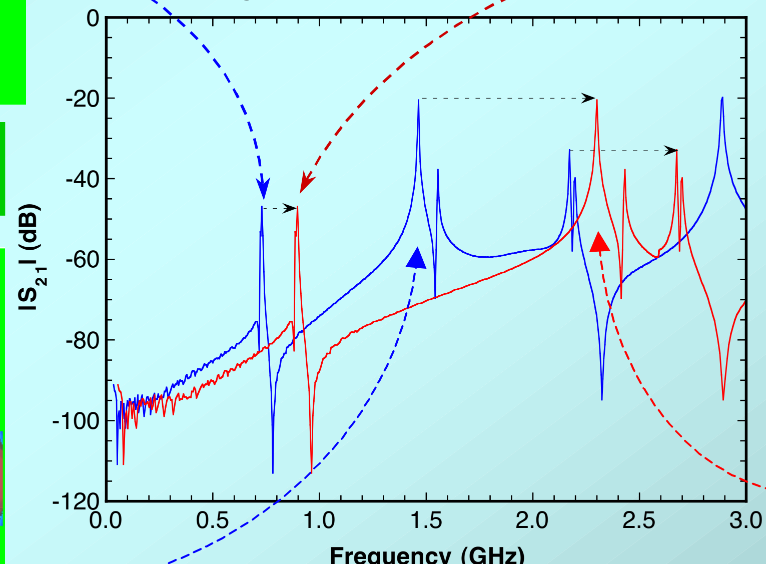


Even Mode



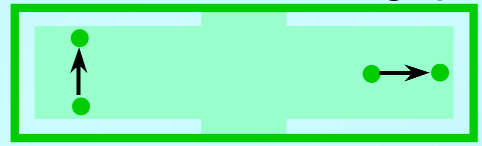
Constant Electric Energy Surfaces

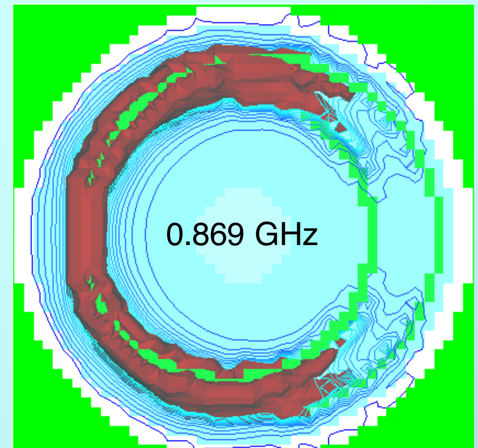
Comparing the dielectric-with-air-gap to the dielectric-filled cavity, odd modes shift only slightly higher in frequency due to small fringing fields in the air gap while even modes are shifted to considerably higher frequency since the fields for these modes are concentrated in the air gap

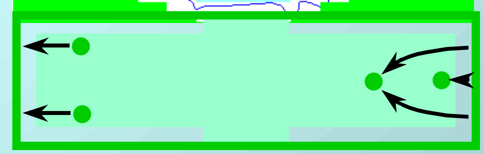


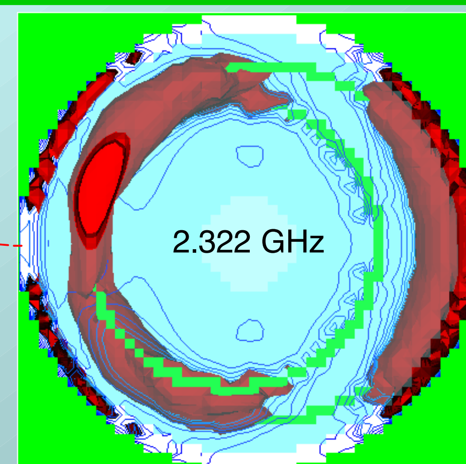
simulated responses for the dielectric filled and dielectric puck with air gap

dielectric with air gap

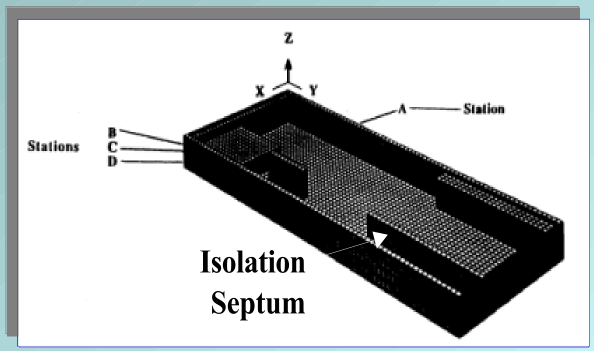




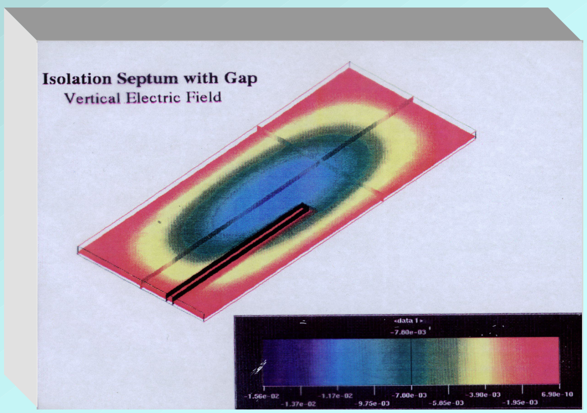




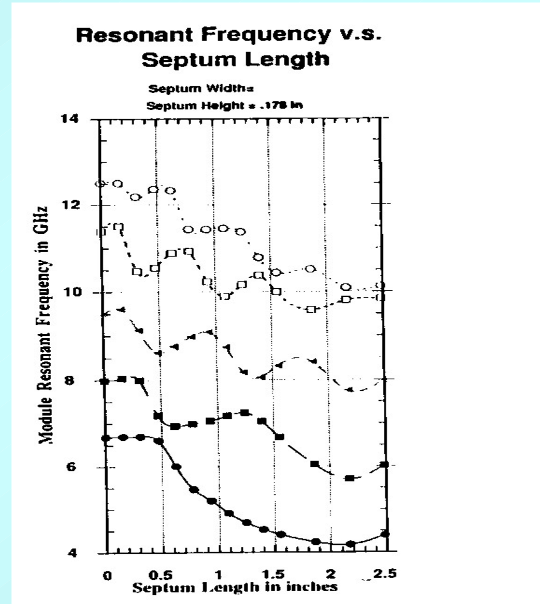
Packaging Simulation

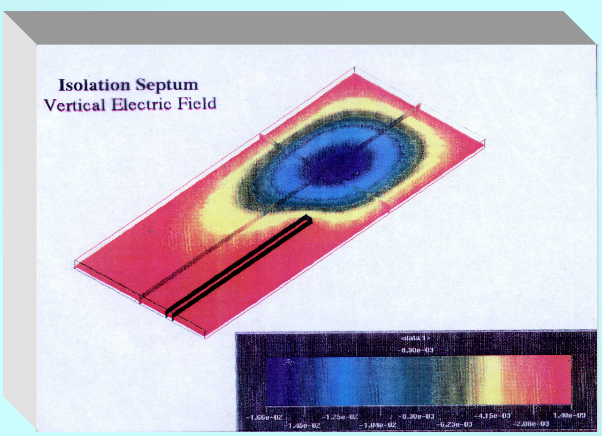


- **Isolation Septum**
  - Shields regions from high fields
  - Shifts mode frequencies out of band

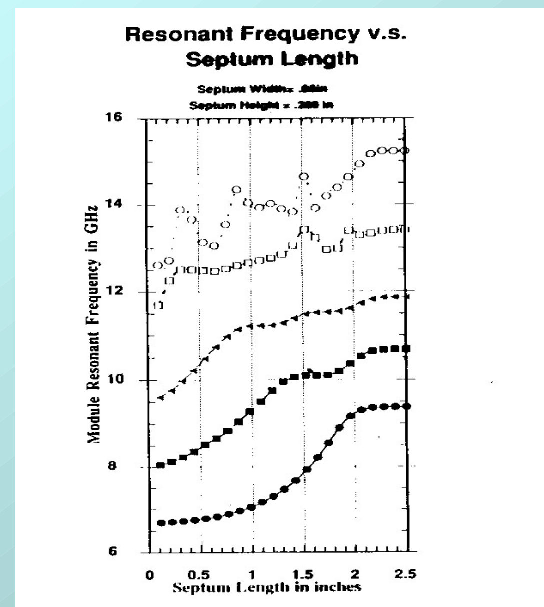


- **Isolation Septem Not Connected to Lid**
  - Field NOT shielded
  - Frequency decreases and stays in-band





- **Isolation Septem Connected to Lid**
  - Field shielded
  - Frequency increases and shifts out of band



Summary / Conclusions

- CTLSS can be used for both vacuum electronic and RF solid state circuits applications
- Good agreement obtained between CTLSS predictions and measured resonant frequencies of Mobius filter
  - CTLSS predicts reduction of non-Mobius modes by use of dielectric puck and air gap
- Future advances in CTLSS will provide more opportunities for application to RF solid state circuits